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SOIL CONSERVATION IN THE COLONIAL EMPIRE.*

WE need make no apology for reverting to the perennial problem of erosion, for it is and for a long time will be the directing force in the development of applied science to the soil in every country that still has its human climax in front of it. If one omitted soil conservation work from an account of the soil research of the oversea Empire there would be little left; and if every research worker were engaged in attempting to solve the problems created by erosion there would still be plenty of room for more recruits.

"A Review of the Position in regard to Soil Conservation in the Colonial Empire in 1938" has recently been circulated to administrative officers in the Colonial dependencies by the Colonial Secretary, following up a similar review issued for 1937†. The Review was prepared for consideration of the Colonial Advisory Council of Agriculture and Animal Health and consists of reports from twenty-eight separate territories situated in or near the tropics, and, with its predecessor, forms a unique contribution to the scanty literature of tropical soil conservation. It gives a remarkable picture of the very varying facies of the erosion problem as it presents itself in South, East and West Africa, in the West Indies, in the Mediterranean, in Ceylon and Malaya, and in Fiji and St. Helena. Most of these regions are inhabited by races who in their backward condition had not learnt how to master and destroy the soil, but can now do so and must be unlearnt by their white teachers and rulers.

A very valuable feature of the review is that most of the reports are written not from the point of view of the specialist in soils or plant ecology whose goal is to procure a stable soil or plant cover, but from that of the administrator whose goal is a stable human society. The intertwining factors of climate, soil, vegetation, agricultural and pastoral practices, social customs, land tenure, world economics and religion are seen if not in their proper perspective (for the problem is still too obscure to talk of perspective), at least without over-emphasizing one factor to the neglect of others. The administrator may sometimes feel that he cannot distinguish and treat the separate trees as he would like, owing to the obscurity of the wood, but where it is a matter of national

* Reprinted from *Imperial Bureau of Soil Science, Soils & Fertilizers*, Vol. 3 No. 2, pp. 49-51, 1940.

† These Reviews are not for sale.

life or death the wood is of far greater value than any number of separate trees. In other words, one does not aim at complete erosion control, ideal forestry, economic security or justice for all, but at a compromise which will allow social evolution to muddle along somehow. In the past, first consideration has been given to the welfare of the natives (and of the ruling interests) and the soil has been abandoned to its fate; in the immediate future and so long as the direction of conservation policy is kept in the hands of officers who have other things beside the soil to think of, there is little danger of the people's interests being pushed too far into the background in order to save land which the people would not be in a position to enjoy.

The same considerations apply, of course to temperate regions also, but in the tropics, the people are generally less well situated to put a self-preserving political brake on the activities of conservation enthusiasts. Colonial administration is, however, healthily departmentalized and inter-departmental instincts of self-preservation operate in the same way as do individual instincts in temperate regions to preserve a rough balance between the interests of the soil and of the people, animals and plants which produce and are produced by the soil. At the beginning of the conservation era (*circa* 1930) departmental interests frequently clashed over questions of conservation—the veterinarians for instance were out to save cattle which the soil-savers would have preferred dead—but these reports indicate a marked trend towards inter-departmental co-operation and towards a realization that such co-operation must be the keynote of conservation policy in the tropics, just as individual co-operation is now recognized as the first indispensable in saving lands in which each man claims the right to assert his equality with his fellows. The extent to which the co-operative principle has been realized and acted upon might be taken as a convenient measure of the distance any country, whether tropical or temperate, has travelled out of the soil-eroding (pioneer) into the soil-conserving stage of its social evolution. The tropics have a long way to travel—the major problems of racial co-operation which is fundamental to the issue of soil conservation have still to be tackled—but the British dependencies as a whole can justly claim to be well in the vanguard.

A good example of how an apparent conflict may resolve itself into a community of interests protecting the land for the people is illustrated by the changing attitude towards tsetse-fly control in relation to soil conservation. At one time the fly tended to be regarded as one of Nature's surest shields against man-made erosion, but in at least two territories it has been shown that fly control may be made to play a positive part in a comprehensive conservation programme. The Director of Veterinary Services in the Gold Coast reports that clearing the fringing forests on the banks of rivers not only does not cause erosion but actually arrests the process where it had previously been occurring. After clearing and burning, a profuse growth of grass springs up which effectively stops all erosion and binds the river banks more securely than does the natural forest vegetation. In Tanganyika, " fly " country is being cleared of bush and used for regulated grazing in order to relieve the pressure of stock in other overgrazed and eroding land. It might be said that a certain concentration of erosive forces is being diluted to a less harmful and more manageable strength by spreading them over a wider area. The entomologist and conservationist are no longer working at cross purposes in making a habitat fit for man.

Again, veterinary departments, while not relaxing their struggle with disease, are paying increased attention to the possibilities of raising the quality of stock by breeding, culling, selection, &c. If a general rise in quality could be achieved, a fall in quantity would almost inevitably follow and the greatest obstacle to the conservation of pastoral land would be removed without invoking Nature's harsh methods of dealing with over-population. No satisfactory way has been found of getting the native populations to agree to the drastic restrictions of livestock numbers that are imperative if the land is to be saved. Since cattle are often insignia of wealth, destocking is largely a social matter and would involve a complete reorientation of the economic system of native society. Apparently the natives take no more kindly to attempts to substitute a money-based, for a cattle-based economy than would, say North Americans to attempts to substitute a cattle-based for the money-based economy which has devastated their continent. A self-sufficient community does not, because it dares not, allow the soil to deteriorate, but a money-ruled community has every incentive to cash in on its fertility reserves and get rich at the expense of the soil. Possibly the existence of a cattle-based economy will have to be recognized as a factor to which all other factors in the environment must be adjusted in the process of re-forming a biotic equilibrium. Raising the quality and reducing the quantity of cattle in circulation might be regarded as a kind of financial deflation which, though difficult to carry through, would result in healthier economic conditions all round.

The restoration and improvement of the natural cover on worn-out pastures demand intensive study by ecologists, agrostologists and plant breeders. These experts have not yet been called upon to play a large part in colonial conservation planning. Their services would require the expenditure of considerable sums of money with little prospect of immediate return, and it is an unfortunate but ineluctable fact that industrially undeveloped countries, where the need for ecological research is usually greatest, have not the wherewithal to carry it out.

On the agricultural side the tropical colonies as a rule make relatively greater use of mechanical erosion control (terracing) than do the more

advanced temperate countries nowadays. There is not much evidence that "ecological" engineering is supplanting mechanical engineering to any great extent. This may portend that terrace agriculture will become a permanent feature of tropics, or it may be that the extensive use of terraces is a temporary makeshift until a suitable soil-conserving cropping system has been worked out. As might be expected, terracing is widely adopted on plantation land where there is little scope for modifying the cropping system in accordance with the requirements of soil conservation. Throughout Africa attempts are being made to introduce mixed farming systems which will assure the maintenance of soil fertility and stability, but in most territories the systems have still to be worked out and the present conditions of native land tenure modified to allow the systems to work. Judging from these reports, mixed farming seems to have made rather more progress in West Africa than in East Africa.

Adaptation of the traditional conditions of land tenure to the requirements of settled conservation agriculture is one of the most crucial points in the soil-conservation programme of any country where native land-holders predominate. The importance of land tenure is fully recognized in the reports, but the matter is obviously one of extreme delicacy, requiring very careful handling. It is here that civil and legal departments will become implicated in soil conservation. Legislation—for the control of grazing and burning forest protection, &c.—was enacted in a few territories in 1938, but civil law cannot be a very effective weapon against erosion where the spirit of individual co-operation is weak.

The effect of population density on the incidence of erosion is complicated by numerous factors, but in the type of rather primitive community with which the Review is mainly concerned it would appear that a dense population favours erosion when it practises shifting cultivation, and favours conservation when it practises settled cultivation. Some isolated tribes in Tanganyika have been forced by geographical circumstances to adopt settled agriculture, and their lands are almost free of erosion; others, formerly confined by pressure from surrounding tribes, now have room to expand and are abandoning intensive agriculture for destructive shifting cultivation. In parts of Nyasaland emigration has so reduced the population that a serious difficulty in the way of introducing reforms is the absence of sufficient men to carry them out. In Kenya "the Coast Province . . . . is sparsely populated and erosion is, therefore, not serious", while in another part "overcrowding is responsible for much loss of fertility". The island of St. Lucia, on the other hand, can show quite a close correlation between density of population and standard of agriculture, the latter being described, for example, as "very good" in a district with 552, and "poor" and "very poor" in districts with 95 and 132 persons respectively per square mile. These facts suggest that where the struggle for existence does not compel men to safeguard their land, the community itself may have to impose compulsion on its individual members.

It is indeed remarkable that these non-agricultural aspects of soil conservation should already have asserted themselves in the colonies. That they have done so is an indication of the extent to which erosion has affected the life of the common man, and that their significance has been recognized is an indication of the vigour and comprehension with which this most pressing problem is now being tackled.

REVIEW.

VEGETATIVE PROPAGATION OF TROPICAL AND SUB-TROPICAL PLANTATION CROPS.

By G. St. Clair Feilden, B.A., drawings of propagation methods and accompanying descriptions by R. J. Garner, *Imp. Bur. of Hort. & Plantation Crops*, Kent (Tech. Comm. No. 13), 1940, pp. 99, illus. 19, price 3/6.

This publication is the promised complement to Technical Communication No. 7 (Vegetative Propagation of Tropical and Sub-tropical Fruits) by the same authors, reviewed in Tropical Agriculture of November, 1936.

The Technical Communications of the Imperial Bureau of Horticulture and Plantation Crops always exhibit a particularly happy knack of giving the practical research worker neither too much nor too little, but just what he wants in the way of information. It is achieved by wide reading, ruthless boiling down, and complete sympathy with the readers' requirements; this last springing partly from the Bureau's close association with research at East Malling, and partly from its incessant care to maintain friendly contacts all over the Empire. The latest addition worthily maintains the standard. It is about as easy to review as an encyclopedia—which, within its scope, is what it is.

There is a foreword by Sir Geoffrey Evans. The illustrated section on methods of propagation in general by R. J. Garner, which was a useful feature of T.C. 7, has been repeated and enlarged. The encyclopedic section ranges from *Actinidia* to *Zingiber* and appropriately allots the greatest amount of space to the more important crops, especially coffee, rubber, tea and cacao. The lay-out, with marginal guides and references, facilitates the enquirer in a hurry, and bibliographies at the end of each crop entry equally facilitate those who desire to consult originals.

E. E. C.

BANANA DISEASES.

XIII. Further Observations on the Condition of Banana Plantations in the Republic of Haiti.

By C. W. Wardlaw.

(Imperial College of Tropical Agriculture, Trinidad, B.W.I.)

I. Introduction: General Observations.

In an earlier Report* (1938), the writer indicated that banana production in the Republic of Haiti was being seriously hindered by (*a*) a condition described as "plant failure", attributed to unfavourable soil factors, (*b*) the spread and intensification of Cercospora leaf disease (Sigatoka disease), and (*c*) Panama disease, particularly in certain districts. After an interval of 18 months, the writer has had the opportunity of revisiting the more important banana growing areas throughout the Republic with the results submitted below.

By way of introduction some general observations may be recorded. The condition noted by the writer in 1938, and described as "plant failure", can be observed in more or less acute form in many areas and a majority of plantations show a preponderance of mediocre to poor fruit. In some areas where "plant failure" occurred in a mild form only in 1938, it is now present in a considerably aggravated form; in other areas though plant failure symptoms may be less spectacular the standard of production has definitely declined.

A majority of privately owned plantations round Cap Haitien and Plaine du Nord are now in such condition as to be incapable of yielding fruit for export. This is due to such causes as failure to provide irrigation water, soil conditions productive of "plant failure", and Sigatoka disease in its final epidemic form. In such instances the owners not infrequently have entirely erroneous ideas as to the cause of their failure, *i.e.* they are not knowledgeable in respect of the crop on which they depend for income. In this connection it would appear that there is a wide and useful field for educational activity.

Not all failures to produce marketable fruit are due to the particular condition described as "plant failure". In the vicinity of Aux Cayes and Jacmel several plantations were observed in a conspicuously poor state of productiveness: inspection showed that drought, inadequate irrigation, poor drainage, grass, need for replanting, inadequate attention to pruning and lack of nutrients were among the factors concerned. On the whole, there is a tendency for private owners to plant up considerably more than they can maintain, as bananas grown on mediocre soils must be maintained, if continuous productiveness is to be ensured. As production declines, they are, more often than not, unable or unwilling to spend the money necessary to rehabilitate their plantations: in fact, the difficult lesson has to be learnt that banana growing is a business that must receive careful attention from start to finish, that half measures are useless, and that unless a fair standard of production can be obtained year after year, the meeting of such contingencies as the control of Cercospora leaf disease, &c., cannot be contemplated. There are few agricultural industries in which the results of malpractice and the effects of disease more quickly become evident than in banana cultivation. Hence the prevalence after brief and altogether inadequate periods of productiveness, of abandoned, semi-abandoned, diseased and non-remunerative plantations which, at the outset, gave promise of continued success.

Pruning and spacing of bananas are generally recognised to be matters requiring special attention in different areas. To ensure maximal productivity and continuity of yield, local experience of growth conditions is essential. Haiti is no exception in this respect. The very close juxtaposition of daughter suckers to parent plants, the erect posture of the leaves, and the prevalence of blowdowns, all contribute to the difficulties of maintaining an orderly succession and distribution of plants. Pruning and spacing of banana plants under Haitian conditions still require careful consideration. On many farms, undesirable conditions such as a disorderly succession of plants, congestion of leaves within the stool, leaf interference with the bunch, daughter suckers growing up into the bunch of the parent plant, too many plants per stool, &c., cannot fail to be observed. These matters should be carefully examined and duly regulated.

The outlook for the banana industry in Haiti during the next few years cannot be viewed with optimism except by those incapable of appreciating the difficulties which are everywhere apparent. In the order of their importance the problems of the banana industry in the Republic are these:

(*a*) the economic solution of the problem of "plant failure";
(*b*) the improvement of cultivation in all its aspects;
(*c*) the control of Cercospora leaf disease;
(*d*) restricting the spread of Panama disease.

Here it may be noted that (*a*) and (*b*) are both concerned with the basic problem of *adequate production*, without which there can be no question of meeting the costs of leaf disease control or other contingencies. Until (*a*) is achieved, it is inadvisable, in the writer's opinion, to attempt a widespread cultivation of the banana in Haiti. The question of new plantings, even in what appear to be favourable areas, should also be subjected to the closest scrutiny, if the present undesirable system of short-lived production is to be avoided.

* Wardlaw, C. W., 1938: Diseases of the Banana in Haiti, with Special Reference to a Condition Described as "Plant Failure". *Tropical Agriculture*, XV, 12, pp. 276-82.

FIG. 1.

FIG. 2.

FIG. 3.

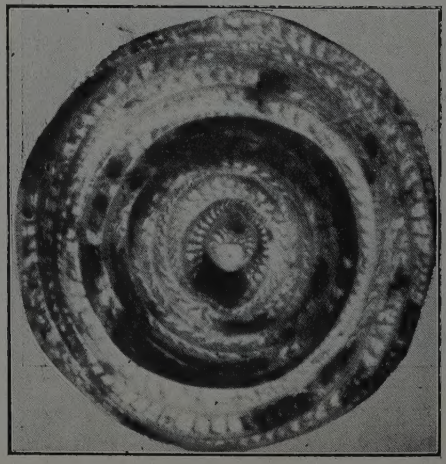

FIG. 4.

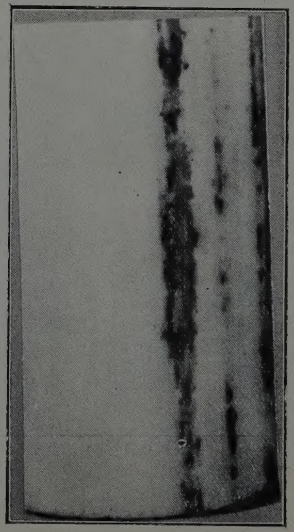

FIG. 5

In concluding this section it may be stated with due emphasis that the principal result of the writer's second visit to the Republic has been to give substantial confirmation to the general and particular findings set out in his Report of 1938. Co-operation among all interested in the industry, continuity of effort, a close scrutiny of outstanding problems, and the propagation of a good working knowledge of the crop among growers of all classes are essential if even the present standard of productiveness is to be maintained.

II. Plant Failure.

A. Additional Symptoms.

The symptoms of the condition known as "plant failure" have already been described in detail. These symptoms are now present in an acute form in some of the older farms and are also becoming evident in new plantations. Additional symptoms noted in severely affected plantations include:

(i) More or less complete destruction of leaves, rotting and softening of the leaf sheaths at the "throat" or "crown" of the plant, and the dropping out of bunches. Both small and large bunches may drop out, the main stalk of the bunch typically breaking, with some localized soft-rotting, at the whitish region some 6 to 8 inches within the throat. This breaking is primarily mechanical: it is a direct result of the failure of the softening petiole bases to give their normal support, the main stalk typically breaking under wind action at the weakest point in proximity to the fulcrum of the main-stalk bunch unit.

(ii) Severely affected plants show a tendency to develop a leaning position, even when the bunch is quite small and light. No doubt wind action is involved, but the evidence of "weakness" so conspicuous in some plantations at the present time is not usually to be observed in normal Gros Michel plantations.

Fig. 1 shows a typical example of plant failure: the bunch is small and occupies an almost horizontal position; only three leaves remain, two of these being brown or yellow-brown in colour. The young plant on the left—the first ratoon—is still green and healthy. There is, however, some congestion at the throat and the petioles tend to assume a rather erect posture. Figs. 2 and 3 show the final stage of "plant failure" when all the leaves have fallen and the bunch is on the point of dropping out.

B. Destruction of Rootlets.

As previously indicated, all the symptoms of "plant failure" so far observed can be accounted for by reference to the extensive and, it would appear, early mortality of the rootlet system. Inspection of the rhizome and main roots of "failure" plants has again shown that these are typically clean and apparently healthy in the sense that they are free from fungal pathogens or insect pests.* The destruction of the absorbing (*i.e.* rootlet) system apparently becomes of increasingly critical importance during growth as the plant proceeds from the vegetative to the fruiting stage: in severe cases of this malady, as indicated above, all functioning leaves may be destroyed and the bunch prematurely dropped.

That destruction of the rootlet system is responsible for the condition known as "plant failure" may now be provisionally accepted. Analysing the situation further, it may be noted that the destruction of rootlets might be due to several factors, operating singly or in conjunction: (i) fungal or bacterial pathogens; (ii) toxicity of a more or less direct nature resulting from the high alkalinity of the soil solution; (iii) nutritional defects.

In order that the problem may be thoroughly investigated, and to clear the way for the work of the Soil Chemist, it is obviously desirable that an investigation of dying rootlets should be undertaken by a competent pathologist. Once rootlet injury (denoted by the appearance of purple colour) has been sustained, it is to be expected that various fungi, including saprophytes and facultative parasites, could be isolated from the cortical regions. Such observations must be treated with due caution.

It may be noted at this point that although the mechanical condition and moisture status of the soil as well as various agricultural practices may increase or diminish the intensity of "plant failure", the body of evidence so far obtained points to some chemical factor or combination of chemical factors as being of paramount importance. The need for physiological investigation is also evident from the data so far obtained.

III. Alkali Chlorosis.

Alkali Chlorosis of bananas, the symptoms of which have already been described in some detail (1938), is still present in a conspicuous form at Delugé and elsewhere in small areas throughout the Republic.

In view of the smallness of the areas affected, and having in mind the number of major banana problems that await attention, the most evident course of action at the present time is to abandon these unproductive areas.

In making this recommendation the writer is not overlooking what must be a fairly evident observation to all who visit such areas, namely, that very good fruit may be obtained in close proximity to chlorotic areas.

IV. Cercospora Leaf Disease (Sigatoka Disease).

A. General Notes.

Before proceeding to an account of Cercospora leaf disease in Haiti, some general observations based on experience elsewhere may be set out:

* Evidence of what appears to be eelworm activity was observed in roots in one plantation.

(i) Cercospora leaf disease can be controlled by the application of Bordeaux mixture or other copper-containing sprays, but knowledge of local meteorological conditions, rate of development of leaves, and seasonal intensification of the disease, is necessary in order that control measures may be undertaken at minimum cost.

(ii) In general, spray control has proved superior to dust control: the latter is expensive and does not give the same certainty of control as spraying does.

(iii) The control of severe leaf disease in fully grown plantations is difficult and costly, and, as a rule, requires a considerable period of time to achieve: experience has shown that the best procedure is to cut down all plants in affected areas and to secure control as the young plants come up.

(iv) Considerable difficulty has been experienced in obtaining control in young plantations situated in close proximity to severely affected areas. Instances are known where control could not be obtained until the adjacent diseased plantations had been cut down.

(v) Adult leaves as well as young leaves are susceptible. It is therefore advisable to spray the entire stool or mat thoroughly on each occasion, continuing through to the harvesting of the bunch.

(vi) Good spray coverage means good control. The best commercial coverage is obtained when properly prepared spraying liquid is applied under high pressure.

(vii) In regions where growth is rapid, control is sometimes difficult to obtain: a close spraying cycle is necessary, the cycle being only widened when sufficient local knowledge of the disease has been obtained.

(viii) It has been found that it is more difficult to obtain control in the young plant stage than later.

(ix) Spray control makes for an increase in the bunch weight, but injury due to scale insects is accentuated.

(x) Pruning of spotted leaves not only serves no useful purpose but accentuates the effects of the disease.

B. Distribution and Intensity in Haiti.

An inspection of the distribution and intensity of Cercospora leaf disease made throughout the Republic has yielded the following information:

(i) Cercospora leaf disease of bananas is now more or less conspicuously present through the Republic, the intensity varying from a light general infection to very severe leaf scorching.

(ii) As in Jamaica, there is evidence, as yet incomplete, that the conditions (meteorological and/or soil) in certain environments are such as to delay the progress of the disease, or to minimise its intensity. Thus in the plantations round Cap Haitien (with one exception where control with lime copper dust has been practised), the disease has reached epidemic intensity with premature ripening of bunches, whereas in the Artibonite district the infection would still be described as a "light to medium general infection." From the intensity of the infection already present even in the more favoured districts, however, it seems inevitable that control measures will sooner or later be required at least during certain months if production of marketable fruit is to be maintained.

(iii) So far, dusting as practised in Haiti has apparently afforded a fairly good measure of control, but, as the disease increases, it will probably be found necessary to exercise control by spraying with Bordeaux mixture (or other copper-containing spray).

(iv) Several private plantations near Cap Haitien and Plaine du Nord, on which no disease control has been attempted (other than leaf pruning which is *not* effective), are now so severely attacked that practically no bunches of export size or grade can be observed. In view of the fact that prematurely ripening bunches are now to be seen in these plantations, it will be highly inadvisable to accept for export any fruit whatsoever from such areas. (Fruit from plantations severely affected by Cercospora leaf disease usually ripen prematurely during the period of overseas transport.)

(v) If we assume that the potential productivity of the several areas at Cap Haitien under consideration is such as to make control measures economically feasible, it should be pointed out that it will be necessary to cut down the existing stand of plants and to exercise a vigorous control of the disease by spraying from the outset. Taking into consideration the intensity of infection already developed in the district, the control of leaf disease will not be easy: to attempt control on the existing stands of plants will almost certainly be attended with discouragement and failure.

As many of the private plantations inspected throughout the Republic are already in a low state of productiveness because of soil conditions, lack of irrigation, &c., it seems unlikely that the control of Cercospora leaf disease will prove economically possible at the present time. Even on areas where a better standard of cultivation has been maintained, the condition described as "plant failure" so limits the attainment of the desired level of production that it is open to doubt whether or not the costs of Cercospora control can be met. This view was stated in 1938: the persistence and intensification of "plant failure" during the past 18 months requires that it should be emphatically restated at the present time.

C. Other Leaf Spotting.

It has already been noted that small fungal spots are commonly present in great abundance on the leaves of plants in which symptoms of

"plant failure" can be noted. During the current investigations a minute brown spot has been observed to be very widely and profusely distributed on green leaves of the Gros Michel banana. This spotting is in no way destructive as is Cercospora leaf spot, but it should be kept under observation and its cause should be ascertained.

V. Panama Disease.

In the Artibonite district this disease is now definitely on the increase. It is accordingly being kept under close observation and is being treated with killer oil. A localised but severe outbreak has also been observed at Delugé.

In his earlier Report the writer called attention to the inroads which Panama disease was making into the productive banana areas near Jacmel. The position today is serious, the more so as the treatment of the disease has apparently been abandoned. From experience gained elsewhere, it may be stated that the conditions on the light alluvial soils of Jacmel are such as to favour the spread of Panama disease, and newly planted areas, after a brief period of production, will inevitably reach the undesirable condition in which many of the older fields can be seen today.

VI. Bacterial Wilt Disease.

(*Moko Disease*: *Bacterium Solanacearum.*)

The disease, which may be confused with Panama disease, is widely distributed on the Moko, Bluggoe or Probon plantain in the Artibonite district.

VII. Virus Heart Rot Disease.

This disease, recorded and described by the writer in 1938, has been observed on several farms in the Artibonite district, at Cap Haitien, at Delugé and at Jacmel, *i.e.*, it is widely distributed throughout the Republic. In some instances the heart-rot condition, which accompanies the leaf mottling or mosaic symptoms, is very strongly developed; where this occurs the plant is incapable of yielding commercial fruit, *i.e.*, the disease can be as destructive to the individual plant as Panama disease. Fig. 4 shows a transverse section near the top of a pseudostem: the heart-rot condition consists in the presence of brown necrotic pockets of tissue. Fig. 5 shows the necrotic areas in an affected petiole.

Every effort should be made to eliminate infected stools by using the gas oil treatment.

VIII. Pitting and Spotting Diseases of Fruit.

Fruit grown in the Port-de-Paix district has shown evidence of a considerable amount of (*a*) spotting or "pitting" on the cushions and finger stalks, (*b*) spotting distributed over the fingers and (*c*) lesions on the main stalk. This is the disease which has been described as "pitting disease"—the cause of considerable wastage in Brazilian cargoes. Various fungi, in particular *Piricularia grisea* and *Helminthosporium torulosum*, have consistently been found associated with pitting and spotting of fruit grown in Brazil and Trinidad. This disease should be kept under close observation, particularly in respect of its seasonal incidence.

IX. Insect Pests.

The circular scale, *Chrysomphalus personatus* is now very prevalent in the Artibonite district and elsewhere: leaves are conspicuously blotched and fruits are also beginning to be affected. Any further intensification of this pest will call for the application of control measures, particularly during the dry season, but such treatments will not be economically feasible until the major problems of production have been solved.

Active measures against the scale *Aspidiotus destructor* are now being sought in the Republic of Honduras, the intensity of the infection observed there by the writer being comparable with that now being experienced with *C. personatus* in Haiti. A useful lead may therefore be forthcoming from Central American experience in combating this pest.

Thrips injury, which occurs in the form of profuse, minute punctures of the fruit skin, is now very conspicuous in many areas. A considerable measure of success in avoiding injury due to some species of thrips is being obtained in Central America by bagging the bunches as soon after shooting as possible. It is obvious that the production of good quality fruit is necessary to defray the additional expenses involved.

Acknowledgments.

In conclusion the writer desires to express his thanks to the Managing Director and Staff of the Standard Fruit Company and to members of the planting community for the assistance they have given him in enabling him to see all matters relevant to banana cultivation throughout the Republic.

GRASS AS HUMAN FOOD.

It has been established after four years of experimentation by Drs. G. O. Kohler, W. R. Graham and C. F. Schnabel, of Kansas City, Missouri, U.S.A., that grain grasses contain all the chief vitamins, except vitamin D, and that their total content of vitamins is actually twenty-eight times, as large as that of vegetables or dried fruits. In order to make the grain grasses fit for human consumption as an article of diet, the young blades are dried, bleached and finely ground to powder. Either wheat, barley, oats or rye is used. The cost in U.S.A. is six cents per pound, and three factories are already engaged in the manufacture of grass powder. It is claimed that the use of only twelve pounds of dried grass per year per head of population will provide the necessary accessory growth factors for a liberal diet at very low cost.

A REVIEW OF LATENT INFECTIONS CAUSED BY COLLETOTRICHUM GLOEOSPORIOIDES AND ALLIED FUNGI.

By R. E. D. Baker, S. H. Crowdy and R. K. McKee.
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I.—Introduction.

Preliminary investigations on the ecology and parasitism of *Colletotrichum gloeosporioides* have yielded results of some interest and indicate that this fungus should form a promising subject for more detailed research. It is the most abundant of the 'latent infections' of tropical fruits described by Baker and Wardlaw (4) often causing serious damage to mangoes, avocado pears, papaws, citrus fruits, &c. In addition to fruit rots it can cause diseases of the blossom-blight, leaf-spot and die-back types. The objects of this paper are firstly to summarise our knowledge of this and allied *Colletotrichum* species, and secondly to indicate problems still requiring elucidation.

II.—Symptoms and Systematic Affinities.

Strains of *Glomerella cingulata* and of its conidial stage, *Colletotrichum gloeosporioides*, occur commonly on many tropical fruits causing leaf-spots, blossom-blights and fruit-rots. On papaw fruits, lesions caused by this fungus appear as small sunken areas, often brownish in colour, which later enlarge into water-soaked spots. These spots finally become covered with small pink acervuli and the fungal tissue may turn hard and black. Acervuli also occur in large numbers on the petioles of papaw leaves and probably provide the conidia which infect the fruit. Similar lesions are caused on the fruit of the mango, and, in addition, damage may occur as the result of attack on the leaves, petioles and young stems. Lesions on the vegetative tissues of mango trees occur at all seasons and provide conidia which may be carried on to the fruit by wind or rain.

A closely allied fungus, *Gloeosporium musarum*, causes fruit-rot or anthracnose of bananas in storage and also of green unreaped fruit in the field. These diseases have been fully discussed by Wardlaw (17). Like *Colletotrichum gloeosporioides*, *Gloeosporium musarum* is represented by a number of strains, some of which produce perfect stages referable to *Glomerella cingulata*. Thirty-two isolations made from bananas by Wardlaw were investigated by Ashby (1) and placed in three groups as follows.

1. A group represented by the majority of isolations developing numerous orange-pink conidial masses and little or no aerial mycelium.
2. A group with fewer more irregular conidia, dark stromatic growths and more aerial mycelium.
3. A third group regularly producing the perithecia and asci of *Glomerella cingulata* in culture.

In the present work many isolations of *Colletotrichum gloeosporioides* have been made from grapefruit and papaws, and these isolations can be grouped in exactly the same way, although the majority of isolations were referable to group 2 instead of group 1 of the above arrangement. It was noted that isolations from mango leaves often belonged to group 1, while isolations from fruit could be referred to group 2.

Allied species of *Glomerella* cause similar diseases on other plants: for example, *Glomerella Lindemuthianum* (*Colletotrichum Lindemuthianum*), the anthracnose of the bean, and *Glomerella fructigena* (*Gloeosporium fructigenum*), the cause of 'bitter rot' of apples and 'ripe rot' of grapes. Two other tropical diseases, the 'brown blight' of tea, caused by *Colletotrichum Camelliae*, and the anthracnose of coffee, caused by *Colletotrichum Coffeanum*, occasionally produce a perfect stage indistinguishable from *Glomerella cingulata*. Shear and Wood (16) suggest that the name 'anthracnose' should be confined to rots of this type caused by species of *Glomerella*.

The systematic relationships of the conidial stages of these organisms are complicated. Clearly all the 'species' which produce *Glomerella cingulata* as their perfect stage must be regarded as strains of this organism. Shear and Wood (16) and Dey (10) refer to the fungus attacking citrus as *Colletotrichum gloeosporioides* Penz., while Grove (12) adheres to the name under which the fungus was first described, *Vermicularia gloeosporioides* Penz. Duke (11), however, considered that there is no essential difference between the genera *Vermicularia* and *Colletotrichum* and retains the name *Colletotrichum*. Burger (8) published a detailed description of *Colletotrichum gloeosporioides* obtained from various citrus hosts in different localities, and showed that *Colletotrichum gloeosporioides* was a polymorphic species made up of various strains, each having distinct cultural characteristics. These characteristics varied with the medium on which the fungus was grown and saltations occurred within the strains. The position is further complicated by the fact that the genera *Colletotrichum* and *Gloeosporium* are closely allied, differing only in the fact that setae occur in the acervuli of the former and not in those of the latter. Now many isolations of *Colletotrichum gloeosporioides* never produce setae in culture, and only occasionally in natural media on old lesions. They are in all other respects identical with *Gloeosporium musarum*, and no doubt the two species are often confused. Grove (12) states that the genus *Gloeosporium* serves as a conidial stage both of *Discomycetes* (*Pseudopeziza* spp.) and *Pyrenomycetes*. Of the latter some species have a relationship with the *Gnomonieae* while others which when older (? always) become *Colletotrichum* are connected with *Glomerella*. *Colletotrichum* he considers to be essentially a *Gloeosporium* which sooner or

later produces setae in the acervulus. He retains the genus *Vermicularia* for species of *Colletotrichum* which regularly produce large numbers of setae from the start, instead of as an afterthought. *Colletotrichum gloeosporioides* appears to fall into the second of his groups, as its perfect stage is a *Glomerella* and it resembles a *Gloeosporium* which sooner or later produces setae in the acervulus; and not into the genus *Vermicularia*.

Isolations indistinguishable from *Colletotrichum gloeosporioides* have been made by the authors from cacao, and the cacao anthracnose species which include *C. incarnatum*, *C. Theobromae*, *C. Theobromicolum*, *C. luxificum* and *C. Cradwickii*, require reinvestigation. It seems possible that anthracnose of many tropical fruits is caused by strains of *Gloeosporium* and *Colletotrichum* all belonging to the *Ascomycete* species, *Glomerella cingulata* (Stonem.) Sp. and v. Schrenk. Widely differing strains, all presumably referable to this species, occur in Trinidad.

III.—Previous Investigations on Methods of Infection.

The methods by which infection is brought about by anthracnose fungi have been the subject of much work. Hasselbring (13) summarised the early literature and illustrated the appressoria and infection hyphae of *Gloeosporium fructigenum*. He suggested that penetration was effected by a chemical disintegration of the cuticle by substances secreted by the penetration hypha. In later work Brown (6) working with *Botrytis cinerea* found that no such solution of the cuticle took place and Blackman and Welsford (5) showed that the rupture of the cuticle and subsequent penetration was due to mechanical pressure exerted by the penetration hypha. This type of mechanical penetration was illustrated by Dey (9) in the infection of the bean by *Colletotrichum Lindemuthianum*, and later in the infection of lemon leaves by *Colletotrichum gloeosporioides* (10).

Dey found that the spores germinated readily in pure water but that they were very sensitive to a rise in temperature. Germination was good at 80°F., poor at 85°F., and practically inhibited at 90°F. The appressoria were formed at the ends of the germ tubes as the result of contact with any hard surface. Further development of the appressoria would not take place in pure water but if a nutrient, in concentrations as low as a 0.1 per cent. solution of glucose, was added, the appressoria would germinate. Dey demonstrated that a sufficient concentration of nutrient material to stimulate the germination of the appressorium was supplied to the infection drop from the surface of the host, probably by exosmosis (7). On young lemon leaves appressoria were seen after twelve hours, and minute brown spots, indicating infection, after 72 hours. The appressoria would not stand desiccation in vitro.

It has been shown by Baker and Wardlaw (4) and Baker (2) that certain fungi may remain inactive in the tissues of the host for considerable periods before the formation of lesions gives a visible clue to their presence. This type of infection was termed a 'Latent Infection'. Such infections have been demonstrated in many tropical fruits, several fungi, including *Colletotrichum gloeosporioides*, being involved. It was further demonstrated that the infections could occur early in the development of the fruit and that they were confined to the upper layers of the rind. Irrespective of the age of the fruit at the time of infection, lesions only become visible when a certain stage of ripening or senescence has been reached. Baker (2), however, found that the behaviour of the papaw was anomalous in that no latent infections were established, except near the stem end where water may be expected to accumulate, until the fruit was nearly mature.

IV.—Experimental Methods.

The germination of the conidia of *Colletotrichum gloeosporioides* was examined on glass slides, in hanging drop cultures, and on the surface of fruit. The effect of atmospheric humidity on the germination of the conidia was also tested. Thin surface sections of the fruit mounted in glycerine jelly containing water-soluble aniline blue or in lacto-phenol and cotton blue, enabled the conidia and appressoria to be seen clearly.

Latent infections were established artificially by the inoculation of papaw and mango fruit with suspensions of conidia. These infections were allowed to develop under aseptic conditions as follows. Periods of 12, 18, 24, . . . 72 hours, during which the fruit was held in a saturated atmosphere, were allowed to elapse after inoculation and then the fruits were surface-sterilised with a saturated solution of borax followed by immersion for five minutes in a 0.1 per cent. solution of mercuric chloride. They were then wrapped in cellophane which had been sterilised with alcohol. The ends of the package were plugged with cotton wool to allow gaseous exchange, and the fruits were stored at a tropical temperature until the lesions had developed. To make a quantitative estimation of the infection established, areas each of approximately one sq. cm. were marked with Indian ink on the surface of the fruit, avoiding the stem and stylar ends, and inoculation was confined to these areas. The number of areas showing infection was compared on inoculated and uninoculated control fruit. Before these experiments were started, a number of fruit of various ages, marked in this way, were allowed to rot, and the percentage of squares showing infection was noted. These figures gave an estimate of the degree of natural infection.

V.—Experimental Results.

(1) Spore Germination.

No unusual features were observed either in the germination of the spores or in the formation of the appressoria of *Colletotrichum gloeosporioides*. On glass slides and in hanging drop cultures, conidia usually germinated very slowly and irregularly in water, and the appressoria were formed only after 18 or 20 hours. Dried smears

Fig. 1.

Fig. 2.

Fig. 3.

For Explanation of Figures *see* Text.

of conidia from mango isolations germinated readily in about seven hours when held in a saturated atmosphere at 80°F. The time for germination was much reduced if the conidia were germinated in a nutrient solution such as two per cent. malt, and appressoria were found after five hours. Conidia in water germinated readily on the surface of fruit of all ages and appressoria were seen regularly nine hours after inoculation (Fig. 1). In drops of two per cent. malt on the surface of fruits they were formed after five hours. All observations were made at a tropical temperature of 80° to 90°F. These results show that like many other fungi, *Colletotrichum gloeosporioides* only germinates slowly in pure water, but that the rate of germination is increased if a nutrient is added to the infection drop.

Conidia were found to be very sensitive to atmospheric humidity and germination was practically inhibited below a relative humidity of 95 per cent. On slides over calcium chloride the spores did not remain viable for more than about 70 hours. It was also observed that when fruit were inoculated, an initial period with the relative humidity at or near the saturation point was essential for infection, but that this period need not last for more than 12 hours, provided that the fruit are not immediately subjected to abnormally dry conditions.

(2) The Infection of the Fruit.

The natural infection of a full green papaw fruit is such that if squares, each approximately one sq. cm. in area, are marked on it in Indian ink, about 20 per cent. to 50 per cent. will contain a lesion of the fungus. On inoculated fruit a percentage of 90 per cent. to 100 per cent. was taken to indicate that artificial infections had been established.

On full green fruit it was found that infections were established after 24 hours in a saturated atmosphere, while on young fruit heavy infections were established only after 42 hours. The significance of lighter infections of young fruit which appeared after 12 hours will be discussed later.

When a young fruit was inoculated with a suspension of spores in two per cent. malt, heavy infection occurred after 18 hours, but again a low percentage of infection was found after 12 hours. Appressoria are formed as quickly on young as on old fruit.

Young mango fruit are infected as quickly and readily as old papaw fruit, but older mangoes cannot be infected so easily and their behaviour corresponds closely to that of young papaw fruit. The intensity of infection on a mango reached a maximum when the fruit was about half developed, and then decreased.

VI.—Discussion of Results.

It has been shown that conidia will germinate in water and form appressoria in nine hours on the surface of fruit in a saturated atmosphere at tropical temperature, and that on susceptible fruit under natural conditions infection will then follow automatically. The presence of a nutrient in the infection drop increases the speed of germination very considerably, and an adequate supply of nutrient is normally supplied to the infection drop from the fruit, presumably by exosmosis as demonstrated by Brown (7). The fact that an initial period of saturation is essential for infection but that this period need not extend for more than 12 hours indicates that a period of saturation is essential for the germination of conidia, but that the appressoria which Dey (10) found would not withstand desiccation in vitro, derive sufficient moisture for their further development from the fruit itself.

It is probable that both stomatal infection and direct cuticular penetration occur. An indication that this is so is seen in the 20 to 50 per cent. infection of young papaw fruit after 12 hours, 18 hours before the heavy infection due to cuticular penetration develops. The early infection is attributed to direct stomatal penetration. It is likely that this stomatal penetration also takes place in mature fruit, but it cannot be demonstrated by our technique as the natural infection has already risen to 20 to 50 per cent. Mango leaves are more easily infected through their lower surfaces, and this fact, coupled with the presence of brown staining followed by lesions round the stomata, is taken as evidence that stomatal infection can occur (Fig. 2).

It has been shown that when two per cent. malt was added to the infection drop on a young fruit, heavy infection occurred after 18 hours, while without the addition of malt, infection was delayed for a further 24 hours. It is possible that the time taken to establish infection after inoculation with spores in water can partially be attributed to the time taken for the exosmosis of nutrients from the fruit. This suggests that the skin of a young papaw fruit is less permeable than that of a mature fruit and it probably explains the lack of infection on the sides of the young fruit, while infections occur at the stem and stylar ends where water may be expected to lodge. Older mango fruit also seem to acquire resistance to infection, and their behaviour corresponds closely to that of the young papaw fruit. The decrease in the intensity of the latent infections in mango fruit after they are half grown may be explained by a spreading out of those infections already present by the growth of the fruit, and the increasing resistance of the fruit making further infection under natural conditions more difficult.

Attempts were also made to demonstrate the latent infections actually in the tissues of papaw fruits by means of fixed and stained microtome sections. They were unsuccessful, but the presence of infections in inoculated tissues was indicated by the frequent occurrence of secondary cambia in the layers of cells immediately below the epidermis of papaw fruit, giving the appearance of a typical wound reaction. Such infections

were invisible to the naked eye, so it is obvious that naturally occurring latent infections are very small (Fig. 3).

The conditions for infection therefore seem to be firstly, a plentiful supply of spores, which can be inferred from the general distribution of the fungus; secondly, fruit in a susceptible condition; and thirdly, a period of at least 9 to 12 hours saturation with the temperature below 85°F. In Trinidad, periods of nine hours of saturation occurred during over 200 nights in 1938 even at the height of the dry season, and the night temperature very seldom rises above 80°F. There is therefore ample opportunity for infection to take place throughout the year.

The continuous flowering habit of the papaw would appear to make any control by spraying uneconomic, but the mango has a definite flowering season, and the control of anthracnose and blossom-blight by spraying is possible. Details of the spraying experiments carried out on mangoes have been published elsewhere (3 & 14).

VII.—Suggestions for Further Work.

The foregoing work indicates that *Colletotrichum gloeosporioides* should prove suitable for studies in the physiology of parasitism under tropical conditions. The results obtained with mangoes and papaws have opened up interesting possibilities, some of which are discussed below. Firstly, the question of stomatal or cuticular penetration requires elucidation; secondly, the rate of exosmosis of nutrients from fruit of different ages appears to be of importance; and thirdly, the nature of the resistance of some types of fruit such as young papaws and old mangoes should be examined. Then the nature of the latent infection is still unknown, as is the reason why it is able to develop further when the fruit begins to ripen or reaches a certain stage of senescence. It is assumed that this is due to chemical changes, the precise nature of which has not been determined, in the tissues of the fruit.

VIII.—Acknowledgments.

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IX.—Summary.

1. The systematic relationships of *Glomerella cingulata* and *Colletotrichum gloeosporioides* and the work of Dey and others on the infection mechanism of species of *Colletotrichum* are discussed.

2. Preliminary studies were made on the germination of the conidia of *Colletotrichum gloeosporioides* in vitro and on various hosts. Conditions required for the formation of a latent infection in the laboratory were investigated, and it was shown that in Trinidad such conditions occur commonly in the field.

3. Possible lines for further research are discussed.

X.—Explanation of Figures.

FIG. 1.—Stages in the germination of a conidium. (i) Mature conidium; (ii & iii) Conidium becomes once septate and germ-tube appears; (iv & v) Formation of appressorium; (vi & vii) Penetration of cuticle by infection hypha.

FIG. 2.—Young acervulus on mango leaf. Note unbroken cuticle with conidia already formed below it. An acervulus of this type is about 40μ in diameter and invisible to the naked eye.

FIG. 3.—A 'latent infection' made by inoculation on a papaw fruit. Note cambial cells (shaded) developing around and immediately below a stoma. This type of infection is also invisible to the naked eye.

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AN ACCOUNT OF DIATRAEA SACCHARALIS F. WITH SPECIAL REFERENCE TO ITS OCCURRENCE IN BARBADOS.

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Introduction.

Diatraea saccharalis F., one of the small sugar cane moth-borers, has firmly established itself as the major pest of sugar cane, *Saccharum officinarum* L., in all the commercial cane growing areas of North, Central and South America and the West Indies. Within this wide ecological range it has many regional parasite complexes and pest associates, such as other species of *Diatraea*, and there is considerable variation in the extent of damage which it causes and in methods of control.

This paper is mainly a discussion of the conditions governing the incidence and control of *Diatraea* in Barbados.

Distribution.

Diatraea saccharalis is the most widely distributed of all the American species of *Diatraea* and is found in the United States of America (Texas, Louisiana, Mississippi, Florida), Central America (Mexico, British Honduras, Honduras, Guatemala, Costa Rica, Panama), South America (Colombia, Ecuador, Peru, Bolivia, Venezuela, the Guianas, Brazil, Argentine, Paraguay) and in Trinidad and the Caribbean Islands (Cuba, Jamaica, Haiti, Santo Domingo, Puerto Rico, Virgin Islands, Antigua, St. Kitts, Guadeloupe, Martinique, Dominica, St. Lucia, Barbados, St. Vincent, Grenada). It is not however recorded from the Bahamas or from Tobago. So far as is known it occurs in the New World only.

About 50 species of *Diatraea* are known in the New World (2) but only two other species, namely *D. canella* Hampson and *D. impersonatella* Walk., are serious pests of sugar cane. The range of *D. canella* appears to be limited to the Guianas (British, French and Dutch), Venezuela, Trinidad, Tobago, Grenada, St. Vincent and St. Lucia, and it damages principally ratoon rather than plant canes; *D. impersonatella* is recorded in considerable numbers in some Trinidad cane fields, and is stated to be a minor pest of cane in S. America. Neither species is present in Barbados.

In addition to cane *D. saccharalis* freely attacks cultivated maize, sorghum and rice, and has numerous alternate host plants in wild grasses.

Ecology.

The temperature range in which *Diatraea saccharalis* flourishes varies from marked summer and winter conditions, in which slight frosts may occur and during which the insect has to hibernate, to tropical island conditions where temperature fluctuations are relatively small, where cane is in continuous and overlapping cultivation throughout the year, and where drought diapauses occur but not hibernation. Sugar cane grows in almost as wide a range of soils as of climates. Soils, drainage, and contours influence the growth of plants other than sugar cane, which is frequently the most important factor in the local parasitic complexes of *Diatraea*.

Barbados enjoys the even temperature of a small, relatively flat tropical island fanned by trade winds. Minimum temperatures range around 63°F. and maximum temperatures around 88° to 89°F. Records made in 1933 from May to November with recording thermographs and hydrographs at Codrington Experiment Station show that maximum temperatures inside a cane field were 7° to 11°F. higher inside than outside, and minimum temperatures nearly always 2° to 3°F. lower. Temperatures as high as 95°F. can therefore occur inside cane fields in Barbados, though no such temperatures are recorded outside; with this is associated a recorded range in relative humidity of 30 per cent. to over 100 per cent., which differs frequently from external records.

This combination of temperatures and humidities inside cane fields affect both pest and parasite.

Soils, drainage and altitudes which also affect both pest and parasites vary little in Barbados. The red and intermediate coloured soils in the central hillier area differ little chemically or physically from the black soils of the coastal drier areas but they differ in that planting rates are higher in red soils, and cane varieties are different. There is only a small area of steep contours or poorly drained soils. Fields are small, the average size being just under six acres, though there are of course larger areas formed by contiguous fields. All ground is cultivated save where it is too shallow, and thin soil areas are planted with sour grass (*Andropogon pertusus*) which is not a host of *D. saccharalis*. Cane growth is therefore uniform both in growth and in general distribution over the island, and there is practically no associated plant growth.

The alternate food plants of *D. saccharalis* found in Barbados are *Panicum maximum, Panicum laxum, Echinochloa colona, Eriochloa punctata, Arundo donax, Eleusine indica, Coix lachryma jobi, Setaria geniculata, Vetiveria zizanoides, Axonopus expressus.* These plants are ineffective as natural reservoirs of the insect; apart from their scattered occurrence, they are reaped at frequent intervals for fodder or cattle bedding.

The coincidence of the dry, windy season with the reaping of mature cane, leaving only wind-swept fields of low sparsely growing cane shoots, and the scarcity of alternate host plants for *Diatraea* appear to be responsible for the

limitation of natural parasites to the egg parasite *Trichogramma minutum* Riley. The fact that the dense growth of ripe crop is usually cleared away by May, leaving only the low open growth of young shoots is important. It does not prevent the continuous existence of *Diatraea*, but in conjunction with dry weather, constant winds, lack of natural shelter and alternate host plants is a serious factor against dipterous and hymenopterous parasites, including *Trichogramma*.

Habitat.

As is the case with many serious pests, *Diatraea* is most prevalent in massed growth which gives the optimum of shelter and shade, and optimum conditions of humidity and temperature. Small, isolated and exposed patches of cane are seldom seriously infested.

The original habitat of *D. saccharalis* has been stated to be aquatic grasses (11) and it is considered more suited to high rainfall conditions than to savanna or dry, open grassy lands. In some countries, however, it may be more prevalent in dry areas than in areas of high rainfall or moisture laden atmosphere. There is also conflicting evidence as to its economic prevalence in the same areas in years of low and of high rainfall. This may be due in part to the fact that it has become adapted to commercial sugar cane cultivations and has largely lost its original habitat characteristics. Ecological factors, particularly temperature and wind, have a profound influence on the effectiveness of parasites and on the larval survival of *Diatraea* and therefore on the damage caused by it.

Habits.

The adult moth of *D. saccharalis*, being a night flier and secretive, is rarely seen by day even in heavily infested cane fields. The moths are attracted to lights and large numbers can be taken in light traps. Moths caught in Barbados showed a normal proportion of females, and a high proportion of them were entirely or partially unspent in respect of egg laying.

The eggs are laid in flat single layer masses exposed on any part of the cane leaves. There appears to be no structural differences between cane leaves of different varieties which hinder or stimulate oviposition to any ascertainable degree. There is, however, a difference in the attractiveness of different varieties of cane which causes a greater deposition of eggs in some varieties. This has been referred to by the writer (17) as chemotropism and though it may be important, a precise evaluation of its influence has not yet been possible. Investigations are in progress.

Hatching from the egg usually occurs in the early morning. Dispersal of the young larvae depends largely on moderate air currents which are an important factor in larval survival and in the irregular intensity of infestations (21).

Young larvae feed on surface leaf tissues to a small extent, tunnel into mid-ribs, bore into the erect cylindrically folded leaf spike, and crawl down between the cane stem and the leaves to feed on the inner surface of the basal sheath. The first three types of feeding produce characteristic leaf damage. Survivors from this stage subsequently penetrate the cane stem, usually at the nodes. In view of this habit of young larvae of seeking the shelter of the leaf bases for initial feeding and for penetration of the cane, a variety of cane which sheds its leaves from the stem, or 'trashes' quickly, appears likely to be less severely bored than a variety in which the blades and bases cling to the stem. This effect has been noticed, and also an increase in borer attacks in cane stalks to which the trash clings or 'boots' because of unfavourable growth caused by prolonged lack of rain. Canes with a specially hard surface may also be less liable to attack.

After penetration of the stalk the larvae remain inside the cane until pupation. Very occasionally young larvae come outside, usually in wet weather and in the shelter of a leaf base. Partly mature larvae may migrate from very young canes and from those which have been killed and have started to rot. Inside the cane stalks, the larvae bore in an irregular fashion; sometimes their tunnels run in an almost straight line through the centre of two or three joints or internodes, with no external evidence of the borers' presence; in other cases, the larvae make repeated openings through the rind of the cane and eject their excrement or frass. In other cases the larvae tunnel in a circular fashion just above a node, and so weaken one internode that the weight of the top growth, or a gust of wind, causes the cane to break. Occasionally the growing point of the cane is killed, in which case the entire cane dies down, or survives by sending out lateral shoots. The final, or pupal stage, is invariably passed in a protected situation inside the cane stem, near to the opening of a specially constructed sealed emergence hole.

The phenomenon of larval diapause, caused by prolonged lack of rainfall at the season when rains normally fall, has been proved in Barbados in 1934 (19) and in 1939. In these years many thousands of *Diatraea* larvae were collected throughout the island for breeding the introduced parasites *Lixophaga diatraeae* Tns. and *Metagonistylum minense* Tns. A very high proportion of these larvae pupated within a few hours of being disturbed even though they had not apparently reached full size; in addition, there was an abnormally high proportion of pupae in the material collected. This continued week after week causing inconvenience in the work of rearing larval parasites. It was attributed to prolonged lack of rain, low humidity, and resulting stunted cane growth and it affects the incidence of the borer. The population level of *Diatraea* is temporarily lowered, but with the

return of favourable climatic conditions, the pest is in a position to regain much lost ground, and does so moreover on a host plant weakened by adverse conditions and slower in recovery. The pest is also attacked less than normally by *Trichogramma*, which is more severely affected by the same adverse conditions and by the reduced number of *Diatraea* eggs. This would presumably apply to larval parasites also, should they ever be established in Barbados.

Parasites and Predators.

The principal parasites of *Diatraea saccharalis* belong to the orders Hymenoptera, which attack the egg, late larval stages and pupa, and Diptera which parasitise the larvae. There is however a dipterous pupal parasite recorded from Colon. Predators include Hymenoptera, Arachnida, Dermaptera, and possibly other occasional insect predators, and vertebrates, attacking all stages from egg to adult.

Hymenopterous Parasites.

The principal hymenopterous parasite is the egg parasite *Trichogramma minutum*, which is found in every region where *D. saccharalis* is present; several biological races (6) are known. Another hymenopterous egg parasites, *Telenomus* (*Prophanurus*) *alecto* Crawf., is recorded from many countries from Puerto Rico to South America, but it is so much less abundant than *Trichogramma* that it does not appear to be effective.

There are numerous hymenopterous parasites of the larval stage in the families Ichneumonidae and Braconidae. None of these attains a high rate of parasitism, and though in some countries there may be a local abundance, their combined effect, even when two or three species are present, is not great, and no success has attended their transference from one country to another in the New World. The species which have been introduced into Barbados are *Ipobracon grenadensis* Ashm. and *Microdus diatraeae* Turner; neither introduction was successful (20). The only species found by the writer in Barbados is *Microdus stigmaterus* Cresson; it is doubtful whether this is an introduced parasite, for it has a very wide range of distribution. The extent of parasitism found in Barbados was seven out of 38,132 *Diatraea* (0.018 per cent).

Hymenoptera however include an important egg predator in the shape of certain Formicidae. G. N. Wolcott has found the ant *Monomorium carbonarium ebenium* Forel to be a regular and important predator of the eggs of *D. saccharalis* (25). Unfortunately it attacks both parasitised and unparasitised eggs, which lessens both its own effectiveness and that of *Trichogramma*, though the combined effect is usually greater than that of parasite or predator singly. Egg predators found in Barbados are mentioned later.

There are also Hymenoptera which parasitise the pupae of *D. saccharalis*. They are mainly Chalcididae and appear to be both local and unimportant. None of these is known in Barbados.

Dipterous Parasites.

Dipterous parasites of the larval stage of *D. saccharalis* are numerous and important. *Sarcophaga stenodentis* Tns. is recorded by Van Dine (24) from Cuba, and as introduced from there to Mexico and U.S.A., but it does not appear to be effective. The effective larval parasites are Tachinidae, of which the outstanding species are *Lixophaga diatraeae* Tns., *Metagonistylum minense* Tns. and *Paratheresia* spp. Authorities differ as to their nomenclature. Thus *Lixophaga diatraeae* was formerly *Euzenilliopsis diatraeae* Tns. and in a recent letter (1st July 1939) to the writer, Dr. C. H. T. Townsend, who is an authority on Tachinids, reverts to the name *Euzenilliopsis diatraeae*. As however the writer has seen no published reversion to *Euzenilliopsis*, the well known name *Lixophaga diatraeae* is retained. There is confusion over both the generic and specific names of *Paratheresia*. Four species have come into prominence through introduction for biological control of *D. saccharalis*: *P. signifera* Tns., *P. claripalpis* V.d.W., *P. diatraeae* Brethes and *P. brasiliensis* Tns. American writers place these in the genus *Theresia*, but Townsend (15) says "The reference of these species to *Theresia* is indefensible, and is equivalent to referring the title Theresiini to the one genus *Theresia*. Nor are these flies dexiids. They belong to the family Prosenidae". In the same publication, Townsend calls attention to the fact that "the confusing of these species is responsible for the failure to establish *Paratheresia* in Louisiana" and adds "*Paratheresia signifera* is an arid region species which cannot readily adjust itself to humid conditions, whilst just the reverse is the case with *P. claripalpis*". "Both *P. claripalpis* and *P. diatraeae* are considered (in a letter from Dr. Townsend, 1939) to be suitable to open region light rainfall environment" whereas *P. brasiliensis* is a "forest region heavy rainfall species": *P. claripalpis* therefore seems suited to humid conditions and also to open regions of light rainfall.

There is therefore no doubt that different species of Tachinids are adapted to different ecologies and that in the case of *Paratheresia* it is essential to transfer a suitable species if the introduction of the genus is undertaken at all. So far, all attempts to transfer species of *Paratheresia* away from their natural habitats and ecological limitations have failed, though in some cases (9) the introductions have been made on a very large scale.

Two attempts have been made to establish *Paratheresia* in Barbados. *P. claripalpis* was introduced from Trinidad in 1934 (20) but the material obtained was very limited, and could not be induced to breed on an adequate scale in

captivity. As *Lixophaga diatraeae* was being reared in the laboratory at the same time, in addition to normal mass rearing of *Trichogramma*, work on the refractory *P. claripalpis* was discontinued. The same occurred in 1939 when the writer obtained *M. minense* and *Paratheresia diatraeae* from Brazil. An adequate breeding stock of *Paratheresia diatraeae* was brought to Barbados, but again considerable difficulty was experienced in mating the flies though every device was tried. In 1934 and 1939, however, a few mated females and unmated males and females were liberated in cane fields.

It will be noted that both species introduced into Barbados, namely *P. claripalpis* and *P. diatraeae*, are "open region light rainfall environment" species and might be expected to be suited to Barbados, though it is to be doubted whether the term "open region" includes the wind-swept openness of young cane fields as in Barbados.

Lixophaga diatraeae might also appear to be suitable, but despite the fact that it is easy to rear in the laboratory, and was therefore colonised in Barbados to the extent of 15,676 flies liberated in 1934 and 1935, it did not become established. The natural distribution of *Lixophaga diatraeae* is in a comparatively narrow belt in the Caribbean in which lie the islands Jamaica, Cuba, Haiti, Santo Domingo and Puerto Rico. The parasite has been transferred in great numbers and fostered by artificial means in Louisiana and the United States sugar-belt to the north, and in St. Kitts, St. Lucia, Barbados and British Guiana to the south. It has also been introduced to Mexico. The only success was in St. Kitts, which is not far from Puerto Rico; in Antigua, which is only a few miles from St. Kitts, it has not established itself. The conclusion therefore seems that *L. diatraeae* can succeed only in a limited geographical area.

The most recent introduction of Tachinid parasites for biological control of *D. saccharalis* is that of *Metagonistylum minense* from Brazil to British Guiana, (12), (13) St. Lucia (3), Puerto Rico (1), Louisiana (8), St. Vincent, Trinidad and Barbados (23). The wet area Amazon strain of this fly is distinct in appearance from the dry area Sao Paulo strain. The two strains readily cross and both are amenable to laboratory rearing. Moreover, the Amazon variety appears capable of maintaining itself in the dry Vieux Fort area of St. Lucia, and it was hoped that it would do the same in Barbados, to which the Vieux Fort area has some ecological similarities.

The possibility exists that there are other strains of *M. minense*, and for this reason material was obtained from Minas Geraes, and of the Amazon River strain to be bred for some generations in new areas such as St. Lucia and Puerto Rico. The introduction to St. Lucia has been successful, and can be regarded as an acclimatisation, the tachinid having apparently found suitable ecological conditions away from its natural habitat (3).

By means of cross breeding of strains and acclimatisation of *M. minense* it is hoped to secure a strain which can survive in Barbados; reasons have been given however for doubting whether ecological conditions in Barbados will permit this, and there is no evidence after over eight months of ample field colonisations that this parasite has established itself.

Fungal Parasites.

The fungus *Cordyceps barberi* attacks and kills the late larval stages of *D. saccharalis*. It occurs from Cuba to British Guiana and may have a wider range. Its effectiveness depends largely upon climatic conditions; thus in Barbados, its incidence may be negligible, ranging from under one per cent. of larvae killed in one year to just over three per cent. average in another. In Antigua, however, parasitism by *Cordyceps* can reach 20 per cent. average.

Predators.

There are numerous predators of *D. saccharalis*, particularly of the egg stage. They have not received so much attention as parasites but it is probable that their combined operations in any region are worth studying.

Egg Predators.

In this case reference can only be made to conditions in Barbados, and to Puerto Rico, where Dr. G. N. Wolcott (25) has recorded a predator, the ant *Monomorium carbonarium ebenium* Forel, already mentioned. In Barbados, the writer has found the Acarid *Belaustium* (? sp.n.) destroying egg masses, usually those showing no signs of parasitism, by sucking out the contents. This mite is now far less plentiful owing to increased mulching of the soil. When first discovered it was found to attack *Diatraea* eggs on young cane shoots, at a period of the year when *Trichogramma* parasitism was either absent or very low; it was not found on egg masses when the canes grew taller and denser, though it may perhaps have escaped record.

Another predator which has frequently been taken in the act of destroying *Diatraea* egg masses is the larval form of the green lacewing, *Chrysopa* sp.; it is also a predator on Aphids and other small soft bodied insects, and is recorded as an enemy of the cane fly *Delphax saccharivora* West. in Barbados. A single black ant, not identified, has been found by the writer on two occasions devouring a fresh *Diatraea* egg mass. Ants do not appear to play such an important part as predators as they do in Puerto Rico. The writer has also observed what appeared to be the immature forms of unidentified Psocids feeding on egg masses both hatched and unhatched.

Records of egg masses destroyed by predators in experimental plots at Codrington Station, Barbados show that 7 to 15 per cent. of *Diatraea* eggs (many parasitised by *Trichogramma*) are destroyed by the combined work of the

four predators mentioned. The average for nine months continuous records in 1939 was 10.5 per cent. *Diatraea* eggs destroyed by predators.

LARVAL PREDATORS.

Young larval stages of *D. saccharalis* are doubtless captured by Attid and Argiopid spiders and small lizards which frequent cane leaves. Earwigs are also found in cane borer tunnels with sufficient frequency and with sufficient evidence of their having attacked *Diatraea* larvae to warrant their inclusion as predators.

PREDATORS OF ADULT *Diatraea*.

In view of the nocturnal and secretive habits of *Diatraea* it is not likely that predators of the adult moths have much value. Doubtless cane lizards and spiders are the principal predators.

It can be stated therefore that the predators of *D. saccharalis* are, so far as present investigations have shown fairly numerous, but not effective save for those that prey on the eggs.

Natural Mortality of *D. saccharalis*.

This is an important factor in all countries in which *D. saccharalis* occurs as a pest of cane, and it has received far too little attention and investigation. The determination of natural mortality in the egg stage is usually limited to observations on egg parasitism ; this is satisfactory only if reliable and adequate percentage parasitisms are determined week by week for eight or nine months of the principal growth period of cane. Early larval mortality, though it is an important factor, is seldom measured, if considered at all. It varies greatly from month to month in Barbados (16), and is affected by the type of cane as regards " trashing " of the leaves and hardness of the stem. Late larval mortality caused by larval parasites has received much attention ; in this case also adequate percentages of parasitism should be determined week by week for eight or nine months of the principal growth period of cane.

If these conditions are fulfilled, it is possible to place a value on the factors causing natural mortality of *D. saccharalis* ; this has been done in Barbados (18).

Control of *Diatraea saccharalis*.

CULTURAL METHODS.

These can briefly be stated as methods and density of planting ; time of planting ; frequency of ratooning or reversion to ' plant ' canes ; burning or non-burning of trash after reaping, or burning of fields before reaping ; irrigation and cultivation ; and last but not least, the varieties of cane planted.

NATIVE PARASITES.

Control of *D. saccharalis* by its native parasites has been shown in this paper to be largely a regional matter. The only parasite of *D. saccharalis* which is native to all countries is *Trichogramma minutum* and its various biological races. No other native parasite of *D. saccharalis* is, according to present knowledge, more than an imperfect and fluctuating control in any region.

INTRODUCED PARASITES.

Control of *D. saccharalis* by introduced parasites has received much attention, and much money and labour have been devoted to it. The varieties of parasites have been discussed earlier in this paper. In some cases, these introduced parasites are bred in laboratories, mated, and liberated over wide areas and in considerable numbers for a period of two or more years. Work on these lines is still in progress in some countries, or has been so recent in others that definite verdicts are not yet available (4). Permanent establishment on a proved control basis would appear to be exceptional ; in most cases establishment has not been secured (8).

ARTIFICIAL INCREASES OF NATIVE PARASITES.

This has been carried out in the case of the universal egg parasite *Trichogramma minutum* which is the most effective natural control of *D. saccharalis*. In the New World sugar cane areas this work has been carried out in Peru, Barbados and Louisiana, U.S.A. In Peru it is stated to have been successful (14), and in Barbados 12 years experience over a diverse range of climatic and other conditions, has shown definitely that an economic reduction in the loss caused by *Diatraea* has been secured by progressive increases in the numbers of artificially reared *Trichogramma* liberated in the cane fields (22). The number now liberated has reached 340 million parasites during the principal six months of cane growth.

In Louisiana the experiments of Hinds, Spencer, Osterberger and Dugas over a period of several years were favourable to the use of *Trichogramma* as a control of *Diatraea* (7). Subsequently, however, Jaynes and Bynum (9) reported adversely on its use. Recently Dugas (5) has presented further data on the trend in natural parasitism in Louisiana ; data collected over a period of 11 years indicate that there may be some explanation for the decrease in benefit from artificial colonizations of *Trichogramma* in recent years, as compared to outstanding savings experienced in 1931 to 1934 inclusive, as shown in experiments conducted by the Louisiana Experiment Station.

The effectiveness of *Trichogramma* in its natural occurrence or aided by mass colonisations is subject to fluctuations, mainly due to climatic variations. There is reason to believe both from laboratory experiments and from field experience, that the maximum effectiveness of *Trichogramma* is only secured within a comparatively narrow range of temperature and humidity, which is probably about 90°F. and just under 100 per cent. relative humidity. Its survival capacity, however, extends over a wide range of temperature and humidity. Adverse climatic conditions which reduce the effectiveness of *Trichogramma* are frequently overlooked.

Conclusions.

The prevalence of *Diatraea saccharalis* and its control depend on factors which vary according to country in the wide range of this pest. The principal factors are ecological and vary widely without causing the exclusion of *Diatraea*, but limiting the numbers of its parasites. It is suggested that wind velocity and presence of alternate host plants and shelter are the principal factors affecting tachinid parasites, and that the temperature and humidity range inside the cane canopy are the outstanding factors for egg parasites.

The ecology of Barbados provides an explanation for the absence of most of the numerous parasites of *Diatraea*. *Trichogramma minutum* appears to be the only effective parasite which has accompanied *D. saccharalis* in all the commercial cane growing areas of the New World. It also explains the failure of larval parasites which have been introduced to Barbados in large numbers and which, though breeding freely under laboratory conditions, die in the fields. The effectiveness of breeding and liberating very large numbers of *Trichogramma* during a limited period of each year is also explained ecologically.

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NOTE ON A MUTATION IN CACAO.

A recent article* from the Cacao Institute of Bahia describes an interesting case of mutation in the Brazilian variety of cacao referred to *Theobroma leiocarpa* Bern, as var. *Comum.* Trees eight or nine years old, the progeny of a single mother, were found to be bearing white seeds, and on examination the mother tree itself, 30-35 years old, was found to show the same behaviour, evidently as a result of mutation. This mother tree is described as quite vigorous and well formed, and at the time of inspection was carrying a heavy crop. The mutation has evidently affected a number of plant characters. The sepals, petals, stamens and pistil are described as "immaculately white", though the flowers are otherwise morphologically normal. The fruit is greenish white, ripening yellow, with pronounced furrows but otherwise smooth. The fruit wall, about 18 mm. thick, is described as flexible, easily yielding to pressure of the fingers without tearing, and quite different in texture from that of typical trees of the variety. The young leaves of the flush are almost white and transparent, and the pubescence, more abundant and longer than in the variety "Comum", is also white.

The majority of the fruits contained only seeds with white cotyledons. Seeds with ochre-coloured or pale purple cotyledons were found in 25 per cent. of the fruits, and in these pods all the seeds were pigmented. A mixture of pigmented and white was never found in the same fruit. Among the progeny there were some trees producing only white seeds, and others producing, like the parent, pigmented seeds only in 25 per cent. of the pods. The authors appear to deduce from this that the parent was heterozygous, but it would seem more likely that the pigmented beans are the result of natural crossing with surrounding trees. Failure to find pods containing a mixture of white and purple seeds from the same cause might be purely a matter of chance, but from a heterozygous parent such mixtures would certainly occur. Seedlings raised from pigmented seeds of the mutant sometimes have leaves palmately veined or lobed. This, however, is no uncommon occurrence among cacao seedlings in general.

The authors mention another individual which produces in the same pod a mixture of white and purple seeds. The fruit of this is green, ripening yellow, very much like that of the "Para" variety, and the tree is presumably of different parentage, though that point is not quite clear.

The occurrence of white seeds in *Th. leiocarpa*, though presumably very rare, will interest all botanists working with cacao. In hybrid mixtures of this crop, occasional white seeds usually indicate Criollo genes in the constitution, but the Brazilian case is clearly different and shows that some caution is advisable in arguments based on the occurrence of white seeds in hybrids.

The present writer is indebted to Mr. G. Rodriguez for a translation of the original article which made this abstract possible.

E. E. C.

* Miranda, S. and Silva, P.—"Mutacoes em *Theobroma leiocarpa* Bern. var. Comum". A Bahia Rural, Oct.-Nov., 1939.

CHEMICAL NOTES.

(Compiled by the College Department of Chemistry and Soil Science.)

Chaulmoogra Oils.

Chaulmoogra is the native name of the oil expressed from the seeds of the fruit of the *Taraktogenos kurzii*, and it has been used for centuries in Burma and India in the treatment of leprosy. The tree is widely distributed in Burma, and is also found in Thailand (Siam), eastern Bengal and Assam. The gathering of the seeds is dangerous on account of wild animals, and as the fruit is no longer fresh when gathered the oil is of poor quality and is often adulterated. The name 'chaulmoogra' is also applied to any oil containing chaulmoogric acid, such as *Hydnocarpus wightiana* and *H. anthelmintica*. The latter occurs abundantly in Thailand, Cambodia, Cochin China and Laos, and has been successfully cultivated in Hawaii and the Belgian Congo; its seeds form an article of export to China, where they are known as Ta-fung-chi or Ta-feng-tzu. *T. kurzii* has also been acclimatized to Brazil. H. I. Cole and H. T. Cardoso (*J. Amer. Chem. Soc.*, 61, 3442; 1939) find that chaulmoogra oil (from *T. kurzii*) keeps for years if expressed from dried fresh seeds and not from oil seeds, and is non-irritating upon injection. They give the first quantitative analyses of oils from *H. anthelmintica* and *T. kurzii*, finding that they contain hydnocarpic, chaulmoogric, gorlic, oleic and palmitic acids as well as small amounts of lower homologues of hydnocarpic acid. They also give the physical and analytical characteristics of five chaulmoogra oils. One of these (from *O. echinata*) contained no hydnocarpic acid but was very rich in chaulmoogric acid. The true chaulmoogra oil contained the highest percentage of gorlic acid.—(*Nature*, Vol. 145, No. 3669, p. 310, 1940.)

* * *

Pineapple Manuring. *By H. K. Lewcock.*

Applications of potassium fertilizers markedly increased the yield of pineapples. While no distinguishable difference in the rate of growth during the first twelve months was noted between plants receiving potassium chloride and potassium sulphate in the fertilizing mixture, the yield from the sulphate plots was appreciably greater than

that from the chloride plots. The fertilizing value of the nitrogen and phosphorus contained in inorganic fertilizers was markedly superior to that of these elements contained in organic fertilizers. A very pronounced increase in the vigour of growth of pineapples on manganiferous soils was obtained by spraying the plants with iron sulphate at intervals of three to four weeks, particularly during the winter months. Plants grown in paper mulch did not exhibit the same symptoms of iron deficiency during the winter as did those set out in exposed soil. Semi-annual applications of iron filings to the hearts of young pineapple plants corrected the iron-deficiency symptoms, but the plants were markedly retarded in growth compared with adjoining plants that had been treated with iron sulphate spray. There were indications that iron present in a soil with a low buffer capacity can be made available to pineapple plants by suitably adjusting its reaction, whereas it cannot be so released in a highly buffered soil.—(*Chemical Abstracts*, Vol. XXXIV, No. 3, Col. 844, 1940.)

* * *

Jamaica Rum in Puerto Rico.

R. Arroyo and M. Manzano, in *University of Puerto Rico Agr. Expt. Station Report for* 1937-38, pp. 26-27.

A method for the fermentation and production of a Jamaica type of rum for export has been developed which considerably shortens the time required in Jamaican practice. The method makes use of definite fermenting organisms, and is carried out under strict scientific control.

For this type of rum, the culture consists of a specially-selected yeast and a bacterium; the former produces alcohol but is incapable of producing the full taste, body, and aroma, which are supplied by the bacterium. The symbiotic action of the two organisms accelerates the fermenting period, greatly increases the ester content of the rum, and materially reduces the ageing period required to reach maturity of the product. The alcohol by volume is about the same as in the Jamaican process, but the acidity is reduced and the ester content more than doubled (164.7 milligrams per 100 cc. as compared with 357.9 mg. for the Puerto Rico rum).

It is pointed out that the rum should be distilled in batch stills if a high quality product is desired; also, that ester hydrolysis is inevitable if the raw rum is diluted with a mixture of alcohol and water that has been "cured" for as long a time as possible.—(*Facts About Sugar*, **35**, 4, p. 38, 1940.)

* * *

Soil Crumb Caused by Micro-organisms.

The mucus produced by bacteria was found to be an effective binding agent in the formation of water-stable soil granules. Bacterial mucus from Austrian Field-Pea nodule-bacteria and various other bacterial species, grown on artificial media, produced water-stable aggregates when incorporated with soil. This was true whether the soil contained a large amount of clay or consisted entirely of quartz sand.

The addition of sucrose to soil containing bacteria or fungi, and followed by an incubation period, caused a marked increase in percentage of large water-stable granules. When sucrose was incorporated with soil under sterile conditions and the soil maintained free of micro-organisms, it had no effect on aggregation.

A fungous culture was much more effective than a bacterial culture in producing water-stable granules under aseptic conditions, but it is probable that this relationship varies with different species of both kinds of organisms.

The activities of micro-organisms appear to be of much greater importance in connection with soil structure than their consideration in the past would indicate.—(T. C. Peele, *Journ. Amer. Soc. Agron.*, 1940, Vol. 32, No. 3, p. 204.)

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Cotton Fabric Roads.

In the United States of America, there is a widespread interest at present in the new 'cotton roads' which are being made across the continent from New York to California and from Florida to Maine. According to an article published in *Roads and Road Construction* of April 1, the modern procedure in construction is to lay the cotton fabric on a surface treated with bituminous material. The bituminous material is then applied to the fabric and completely covered with crushed mineral aggregate. The crushed cover material is rolled in and a lighter application of bituminous material is applied and covered with a layer of chips, which are rolled in with a heavy roller. The best results in cotton roads have been obtained from cloth of comparatively open weave. The breaking strength varies between 25 and 45 lb. (grab method) according to grade. The most practicable fabrics cost between 450 and 750 dollars a mile for a road 18 ft. wide.

In New Jersey, cotton fabric and tar were applied on 600 linear ft. of a gravel road in South Brunswick township. After a year of service an inspection was made. Due to snow and light rain for two days, the road and adjoining ground were saturated. On the part of the road where the fabric had not been used, the surface was broken in twelve places. Broken areas were 0.5-1.5 sq. ft. in area and were quite soft. In other places, the surface was resilient and water would ooze to the surface under pressure with a blunt instrument. On the other hand, there were no broken places in the section which had been treated with cotton fabric, and the surface was tougher and less easily punctured with a screwdriver. Recent reports sent in from a number of highway departments indicate that short test sections of bituminous-surfaced roads, having cotton as part of their construction, have decreased maintenance costs, and require less patching. The South Carolina Highway Department has used cotton fabric on bridge surfaces also with a marked degree of improvement in maintaining a satisfactory bituminous surface.—(*Nature* **145**, 3679, pp. 699-700, 1940.)